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Factsheet

IRRIGATION SCHEDULING FOR FRUIT CROPS

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Adequate soil moisture is required for optimum growth and production of fruit crops.

Research has shown that the effect of irrigation on a number of fruit crops can be dramatic. At Harrow, researchers have demonstrated that irrigation not only increases peach yields and improves fruit size, but lengthens peach tree life as well. At Simcoe and Vineland, researchers have also shown that irrigation benefits many crops including apples, grapes, blueberries and pears.

The cost of energy for irrigation has been rising steadily. Applying the proper amount of water at the right time is important for reducing costs and maximizing profits. It is essential, therefore, that there be a scientifically sound method for determining when to irrigate and how much water to apply for optimum crop response and efficient use of resources.

METHODS OF DETERMINING IRRIGATION NEEDS

How can a grower tell when, and when not to irrigate? There are three basic ways.

First, you can test the soil with your hands, giving it the "feel test" to see if the soil "feels" dry enough to irrigate, or if it "feels" moist enough to justify holding off for a while. While this "feel" method is cheap and fast, its accuracy leaves a lot to be desired.

Tensiometers provide a second option. These devices measure soil moisture suction and have been tested on a number of Ontario farms. The difficulty in using these devices is that the reading on the device varies with soil type. Tensiometers are better suited for use on sandy soils, where they monitor most of the available moisture range. In heavy soils, large amounts of available moisture occur outside the detection limits of the tensiometer.

A third method is the water budget approach. The method is based on climatic data and has the following advantages for scheduling irrigation: (1) no equipment requirements; (2) accuracy; (3) simplicity of use; and (4) flexibility allowing easy adaptation for use in other crops.

The water budget approach for scheduling irrigation of fruit crops can be broken into several basic steps, which are slightly different for high-volume sprinkler-irrigated orchards than for those where low-volume drip or micro-sprinklers are used.

A. High-volume Sprinkler Systems

Step 1: Estimate the amount of available water in the root zone.
Table 1 gives estimated available water per unit of rooting depth for soils of various textures. Table 2 gives the average rooting depth to which various fruit crops should be irrigated. The total available water is determined by multiplying the appropriate available water value by the average rooting depth.

Table 1. Ranges in available water capacity and intake rate for various soil textures.

Soil Textures	Available water capacity (mm of water/cm of soil)		Intake Rate (mm/hr)	
	Range	Average	Range	Average
Sands	0.5 - 0.8	0.65	12-20	16.0
Loamy sand	0.7 - 1.0	0.85	7-12	9.5
Sandy loam	0.9 - 1.2	1.05	7-12	9.5
Loam	1.3 - 1.7	1.50	7-12	9.5
Silt loam	1.4 - 1.7	1.55	4-7	5.5
Silty clay loam	1.5 - 2.0	1.75	4-7	5.5
Clay loam	1.5 - 1.8	1.65	4-7	5.5
Clay	1.5 - 1.7	1.60	2-5	3.5

Table 2. Irrigation depth for various fruit crops

Crops	Depth to Irrigate (cm)
Apples	90
Cherries	60
Grapes	90
Peaches	60
Pears	60
Raspberries	60
Strawberries	30

Example:

Given:
Crop type: peaches
Soil type: sandy loam

Calculation:
Total available water in the root zone
= available water (mm/cm) X rooting depth
= 1.05 (mm/cm) X 60 cm
= 63 mm

Step 2: Estimate allowable soil water depletion in the root zone.
Allowable soil water depletion is the portion of the available water in the root zone (around 50%) that can be extracted without causing adverse effects on tree growth, yield and quality. To estimate allowable soil water depletion, simply multiply available water (step 1) by 50%. The allowable soil water depletion for the previous example is 31.5 mm (63 mm X 0.5).

Step 3: Estimate the water use rate of fruit crops.
Table 3 provides information on average daily water use for various fruit crops in southern Ontario as affected by ground cover. The average daily water use rates are

Table 3. Estimated average daily water use rate for various mature fruit crops in Southern Ontario[1].

Month	Date	Apples, Cherries		Grapes	Peaches, Pears	
		clean cultivated	with ground cover		clean cultivated	with ground cover
		Average Daily Water Use (mm)				
May	1-7	1.3	1.8	1.2	1.2	1.7
	8-14	2.0	2.8	1.9	1.9	2.6
	15-21	2.2	3.0	2.0	2.0	2.8
	22-31	2.4	3.2	2.2	2.2	3.0
June	1-7	3.4	4.5	2.7	2.9	4.1
	8-14	3.5	4.6	2.8	3.0	4.1
	15-21	3.5	4.7	2.8	3.1	4.2
	22-30	3.8	5.0	3.0	3.3	4.5
July	1-7	4.4	5.7	3.6	3.9	5.2
	8-14	4.5	5.8	3.7	4.0	5.3
	15-21	4.3	5.5	3.5	3.8	5.0
	22-31	4.1	5.3	3.4	3.6	4.8
Aug	1-7	4.1	5.3	3.4	3.6	4.8
	8-14	3.4	4.4	2.8	3.0	4.0
	15-21	3.2	4.1	2.6	2.8	3.7
	22-31	2.8	3.6	2.3	2.5	3.3
Sept	1-7	2.6	3.6	2.0	2.3	3.1
	8-14	2.4	3.3	1.8	2.1	2.9

[1]Derived from average weekly maximum evapotranspiration at Ridgetown, Simcoe and Windsor using various crop factors (weekly maximum evapotranspiration data from Treidl, 1979. Crop factor data from Doorenbos and Pruitt, 1975).

derived from long-term average weekly maximum evapotranspiration at Ridgetown, Simcoe and Windsor using various crop factors. For example, the average daily water use rates for peaches are 3.9 and 5.2 mm under clean cultivated and with ground cover, respectively, during the first week of July. If available, the actual daily maximum evapotranspiration should be used to estimate the water use rate of fruit crops for scheduling of irrigation (Tan, 1980; Tan and Layne, 1981).

Step 4: Decide when to irrigate.

The starting point for calculating the timing of first spring irrigation is ideally after a thorough wetting of soil by irrigation or heavy rainfall which brings the soil reservoir to field capacity. If this does not occur, the initial amount of available water in the crop root zone must be determined by direct measurement such as tensiometer or oven-dry method. Deciding when to irrigate the fruit crops is determined by subtracting daily water use of crops from total available water in the root zone (step 1) until the soil water has been reduced to the allowable depletion level (step 2). This procedure is illustrated in Table 4.

Step 5: Calculate the irrigation amount.

$$\text{Irrigation amount} = \frac{\text{Allowable soil water depletion (step 2)}}{\text{Irrigation efficiency}}$$

Irrigation efficiency varies with size and uniformity of the fields and climatic conditions. Water application may be lost through deep percolation, runoff and evaporation. Well designed and managed sprinkler systems are generally around 75% efficient. Low volume drip or micro-sprinkler systems usually have much higher irrigation efficiency than high-volume sprinkler systems.

Table 4. Example of a water budget approach for scheduling irrigation of fruit crops using high-volume sprinkler systems.
Soil: sandy loam
Crop: peach tree grown with weeds or ground cover
Total available water: 63 mm (step 1)
Allowable soil water depletion: 31.5 mm (step 2)

Date	Rain (mm)	Water Use (mm)	Total available water (mm)	Irrigation amount (mm)
June, 1987				
1	0.8	4.1 [a]		
2	44.4	4.1	63.0 [b]	
3		4.1	58.9	
4		4.1	54.8	
5	0.4	4.1	51.1	
6	1.6	4.1	48.6	
7		4.1	44.5	
8	1.6	4.1	42.0	
9		4.1	37.9	
10		4.1	33.8	
11	8.4	4.1	38.1	
12		4.1	34.0	
13		4.1	29.9 [c]	
14		4.1	63.0 [d]	42.0 [e,f]
15		4.2	58.8	
16		4.2	54.6	
17		4.2	50.4	
18		4.2	46.2	
19	9.4	4.2	51.4	
20		4.2	47.2	
21		4.2	43.0	

[a] *See Table 3*

[b] *On June 2, a heavy rain of 44.4 mm filled the soil reservoir to field capacity*

[c] *Total available water in the 60 cm root zone fell below the allowable depletion level of 31.5 mm*

[d] *On June 14, a supplemental irrigation of 42 mm filled the soil reservoir to field capacity*

[e] *Irrigation amount*

$$= \frac{\text{Allowable soil water depletion}}{\text{Irrigation efficiency}} = \frac{31.5\ mm}{0.75} = 42\ mm$$

[f] *Application time*

$$= \frac{\text{Irrigation amount}}{\text{Application rate}} = \frac{42\ mm}{9.5\ mm/hr} = 4hr\ 25\ min$$

Step 6: Calculate duration of water application.

$$\text{Application time} = \frac{\text{Irrigation amount (step 5)}}{\text{Application rate}}$$

The duration of water application depends on the amount of water to be applied (step 5) and water intake rate of the soil (Table 1). If you have soil that absorbs water slowly select a system that will apply water at a rate low enough to prevent the soil puddling. For example, to apply 42 mm of water for sandy loam soil (intake rate 9.5 mm/hr, Table 1), the application time should not be less than 4 hrs (Table 4). The same amount of water applied to a clay soil (intake rate 3.5 mm/hr, Table 1) will take about 12 hrs.

B. Low-volume Drip or Micro-sprinkler Systems

Step 1: Estimate average daily water use rate by trees.

Daily water requirements for various fruit crops may be estimated from Table 3. However, with localized irrigation, it is more convenient to calculate water use rate as litres per tree per day than mm per day. Use the following equation for this conversion:

$$LPD = \frac{ET \times 10000 \times AC}{N}$$

where:

LPD = Litres per tree per day

ET = Average daily water use rate (mm) - (See Table 3)

10000 = Factor to convert hectare-mm to litres per hectare

N = number of trees per hectare

AC = Area of shade per hectare, expressed in decimals. Tree ages older than 6 years are considered as a mature bearing orchard. The value of AC equals 1. Tree ages from 1 to 5 years are considered as a non-bearing orchard. Use the following equation for AC:

$$AC = \frac{DS^2 \times 0.7854 \times N}{10000}$$

where:

DS = diameter (m) of shade cast by tree at noon

0.7854 = Constant to calculate area

10000 = Factor to convert hectare to square meter

Step 2: Determine the irrigation frequency.

How often you irrigate is related to several factors: system design, tree daily water requirements, number of emitters per tree and emitter flow rate.

Most low-volume drip systems are designed to operate **daily** and to deliver just enough water to meet the maximum daily tree water use demands. The practice is based on the concept that optimum plant growth may be achieved through preventing moisture stress, by maintaining ideal soil moisture conditions in the tree root zone. Water is applied at low pressure (104 to 138 kPa or 15 to 20 psi) and at slow rates (4.5 to 9 litres or 1 to 2 gallons per hour per emitter) for sufficient periods of time to maintain the soil at or near field capacity.

Many types of low-volume micro-sprinkler systems wet large portions of the orchard soil surface. By taking full advantage of the moisture holding capacity of the volume of soil within the tree root zone, this type of water application will usually meet a 2 or 3 day tree water requirement, resulting in greater flexibility in irrigation. Irrigation frequency for micro-sprinkler systems can be calculated as follows:

$$\text{Irrigation frequency} = \frac{\text{Total usable water in the soil root zone}}{\text{Daily water use (LPD)}}$$

where:

LPD = Litres per tree per day (see step 1)

Total usable water in the soil root zone (litres) = Total usable water per meter of soil depth X total soil root zone reservoir X AC X $\frac{1000 \text{ litres}}{m^3}$

Total usable water per meter of soil depth (m water/m soil) = average available water capacity (mm water/cm soil) (Table 1) X percent allowable soil water depletion X 0.1

Total soil root zone reservoir (m^3)
= area of wetting (m^2) X irrigation depth (m) (Table 2)
= DM^2 x 0.7854 x irrigation depth

where:

DM = diameter (m) of spray for micro-sprinkler

AC = area of shade per hectare, expressed in decimals (see step 1)

1000 = Factor to convert cubic meter to litres

0.1 = Factor to convert mm water/cm soil to m water/m soil

The type of soil (sandy, loamy or clay) will affect the numbers, spacing, and flow rate of emitters. Sandy soils will accept water at a higher rate than loamy or clay soils; therefore, the emitter flow rate may be higher with a shorter operation time. The lateral movement of water for sandy soils will also be less than loamy or clay soils. To compensate for this, emitters usually have to be placed close to trees grown in sandy soils. Clay soils will require a low emitter flow rate to allow for slower infiltration without leaving free water standing on the surface.

Step 3: Calculate the irrigation amount.

Water application amounts depend on the daily tree water use rate, the irrigation frequency and the application efficiency. Low volume drip irrigation systems are generally 100% efficient. Low-volume micro-sprinkler systems are around 90 to 95% efficient.

Irrigation amount

$$= \frac{LPD}{\text{Application efficiently}} \text{ x irrigation frequency}$$

Step 4: Calculate the duration of water application.

The duration of water application depends on the amount of water to be applied (step 3), and the irrigation system application rate. The water application rate can be calculated based on the average discharge rate per emitter or micro-sprinkler and number of emitters per tree.

Application time

$$= \frac{\text{Irrigation amount}}{\text{Application rate}} = \frac{\text{Irrigation amount}}{\text{emitter discharge rate x number of emitter}}$$

Example 1:

Given:
- a 2-year-old non-bearing peach orchard on loamy sand with ground cover
- tree spacing 5.5 m by 3.1 m
- two emitters per tree (low-volume drip systems)
- discharge rate 4.5 litres per hour per emitter at 104 kPa (or 20 psi) pressure
- diameter of shade cast by tree at noon 2 m
- application efficiency 100% (1.0)
- it is the first week in July

Calculation:

Step 1: The average daily water use rate (ET) for peaches under ground cover during the first week in July is 5.2 mm/day (Table 3). Number trees per hectare (N)

$$= \frac{10000 \text{ m}^2/\text{ha}}{5.5\text{m} \times 3.1\text{m}} = 586 \text{ trees/ha}$$

$$AC = \frac{DS^2 \times 0.7854 \times N}{10000}$$

$$= \frac{2 \times 2 \times 0.7854 \times 586}{10000} = 0.18$$

$$LPD = \frac{ET \times 10000 \times AC}{N}$$

$$= \frac{5.2 \times 10000 \times 0.18}{586} = 15.97$$

Step 2: Irrigation frequency = every day for low-volume drip systems

Step 3: Irrigation amount =

$$\frac{LPD}{\text{Application efficiency}} \text{ x irrigation frequency}$$

$$= \frac{15.97 \text{ litres/day}}{1.0} \text{ x 1 day}$$

= 15.97 litres

Step 4: Application time

$$= \frac{\text{Irrigation amount}}{\text{Application rate}} = \frac{\text{Irrigation amount}}{\text{Discharge rate x Number of emitters}}$$

$$= \frac{15.97 \text{ litres}}{2 \times 4.5 \text{ litres/hr}} = 1.78 \text{ hr}$$

Summary

Irrigation schedule: every day
Irrigation amount: 15.97 litres
Application time: 1.78 hr

Example 2

Given:

- same as example1, except using **low-volume micro-sprinkler systems**
- 1 micro-sprinkler per tree
- discharge rate 27 litres per hour at 104 kPa (or 20 psi) pressure
- diametre of spray for micro-sprinkler 4 m
- allowable soil water depletion 25%
- application efficiency 90% (0.9)

Calculation:

Step 1: LPD= 15.97 (same as example 1)

Step 2: Irrigation frequency

$$= \frac{\text{Total usable water in the soil root zone}}{\text{Daily water use rate (LPD)}}$$

Average available water capacity for loamy sand
= 0.85 mm/cm (Table 1)
Total usable water per meter of soil depth
= average available water capacity x percent allowable soil water depletion x 0.1
= 0.85 mm/cm x 0.25 x 0.1 = 0.0213 m/m
Area of wetting = $DM^2 \times 0.7854 = (4m)^2 \times 0.7854 = 12.57m^2$
Rooting depth (depth to irrigate)= 60cm= 0.6m (Table 2)
Total soil root zone reservoir
= area of wetting x rooting depth
= $12.57 \text{ m}^2 \times 0.6 \text{ m}$
= 7.54 m^3
Total usable water for 2-year-old tree at 60 cm soil root zone
= $0.0213 \text{ m/m} \times 7.54\text{m}^3 \times 0.18 \times 1000 \frac{\text{litres}}{\text{m}^3}$
= 28.91 litres
Therefore:

$$\text{Irrigation frequency} = \frac{28.91 \text{ litres}}{15.97 \text{ litres/day}} = 1.8 \text{ days}$$

Step 3: $\text{Irrigation amount} = \frac{15.97 \text{ litres/day}}{0.9} \times 1.8 \text{ days}$
= 31.9 litres

Step 4: $\text{Application time} = \frac{31.9 \text{ litres}}{27 \text{ litres/hr}} = 1.18 \text{ hr}$

Summary

Irrigation schedule: every 2nd day
Irrigation amount: 31.9 litres
Application time: 1.18 hr

Example 3

Given: Same as example 2, except a 7-year-old bearing peach orchard

Calculation:

Step 1: $\text{LPD} = \frac{\text{ET} \times 10000 \times \text{AC}}{\text{N}}$

$$= \frac{5.2 \times 10000 \times 1}{586} = 88.74$$

Step 2: Irrigation frequency

$$= \frac{\text{Total usable water in the soil root zone}}{\text{Daily water use rate (LPD)}}$$

Average available water capacity for loamy sands
= 0.85 mm/cm (Table 1)
Total usable water per meter of soil depth
= 0.0213 m/m (see example 2)
Area of wetting = 12. 57 m^2 (see example 2)
Total soil root zone reservoir = 7.54 m^3 (see example 2)
Total usable water for 7-year-old tree at 60 cm soil root zone (litres)
= Total usable water per meter of soil depth x total soil root zone reservoir x AC x $\frac{1000 \text{ litres}}{\text{m}^3}$

$$= 0.0213 \text{ m/m} \times 7.54 \text{ m}^3 \times 1 \times \frac{1000 \text{ litres}}{\text{m}^3}$$

= 160.6 litres
Therfore: Irrigation frequency

$$= \frac{160.6 \text{ litres}}{88.74 \text{ litres/day}} = 1.8 \text{ days}$$

Step 3: $\text{Irrigation amount} = \frac{88.74 \text{ litres/days}}{0.9} \times 1.8 \text{ days}$
= 177.48 litres

Step 4: $\text{Application time} = \frac{177.48 \text{ litres}}{27 \text{ litres/hr}} = 6.57 \text{ hr}$

Summary

Irrigation schedule: every 2nd day
Irrigation amount: 177.48 litres
Application time: 6.57 hr

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